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Stakeholder integration for the successful product–process co-design for next-generation manufacturing technologies

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ABSTRACT

In Industry 4.0, manufacturing technology has a huge potential of becoming a key facilitator for groundbreaking innovations of products, services, and processes. To exploit this potential, industrial organisations have to transform legacy structures and processes in integrated organisations uniting experts from design, manufacturing, procurement, etc. This research accompanies one of the biggest automotive tier-1 supplier along this transformation. The key objective is to find and analyse ways of integrating different trades in design workshops aimed at the long-term strategic planning the investment in approaches to integrating design, manufacturing, and procurement departments for leveraging Industry 4.0 potentials.

1. Introduction

Manufacturingindustries are confronted with exceptional challenges in an era which is frequently called the "Fourth Industrial Revolution". Modern manufacturing paradigms such as Added-Value and Knowledge-based Manufacturing are mainly characterised by the fact that production is increasingly driven by integrated information technology systems, rendering manufacturing systems more autonomous, flexible and configurable. Megatrends are driving new manufacturing technologies and processes at a speed never experienced before. Additive manufacturing and lightweight materials processing are only two representative examples for technologies confronting manufacturing industries with new and complex challenges. More than ever before these industries have to invest early in know-how and infrastructure to implement production technologies, and adapt them timely both to the rapid technology development and the ever changing product requirements. Industries are therefore looking for methods and tools helping them plan such investments systematically, reliably, and with a holistic view.

This article proposes a systematic yet highly creative process for strategic production planning (SPP) that is entirely based on concepts of integrated design [1]. Its objective is the integrated design of technology roadmaps (TRM) which are an established decision support tool for long-term technology planning in industrial organisations. Section 2 explains the context, the research objectives and methodology. Section 3 summarises the state of the art of SPP with a particular regard to TRM. Section 4 presents the integrated design principles based approach to SPP that we have developed. Section 5 elaborates on the validation of this approach in the context of one of the worldwide largest automotive tier-1 suppliers in Germany. Section 6 concludes with a summary of the key contributions and an outlook.

2. Target and methodology

The objective of this research is to elaborate a systematic and actionable approach that helps industrial organisations plan their future investments and activities in modern production technology and the related processes and organisations. Having led and participated in numerous technology planning sessions, our fundamental hypothesis is that strategic production planning in an Industry 4.0 context has a lot of characteristics in common with creative integrated design processes for new products, services and processes (NPD): [2]

(1) the outcome of the planning is unknown at process start,
(2) the artefacts to be designed are highly interdisciplinary in their nature thus requiring experts from several different trades to actively participate in the process,
(3) only a relatively small number of key requirements to the process and the final outcome are given at the beginning, whereas the identification and formalisation of requirements and constraints is part of the design process,
(4) The outcome of the process is subject to evolution, driven by requirements changes as well as the changing context.

Hence, our quite natural idea and assumption is to find a means to carry out SPP as a creative integrated design process, bringing together experts from diverse organisational units. To validate this hypothesis based on published and own experiences, we designed a novel structured ideation process taking into account the constraints we face in stage-gate process driven organisations, and for the particular objective of SPP, and applied it in a pilot project at an automotive tier-1 supplier over one year.

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3. Key findings about the state of the art

In order to analyse the state of the art of SPP with a particular regard to TRM, we have carried out a systematic literature review using bibliometric analysis facilitated by CiteSpace. We can only present very few key insights of this analysis here. Motorola was the first to publish about the use of a technology roadmap as a tool for better integration of business and technology strategy [3]. Over the last few years, roadmapping has been gaining momentum as a strategic management tool for organisations to better adapt themselves to modern marketplaces [4]. While the roadmap is fairly simple in structure and concept, its content is the result of complex processes. Implementing these processes and measuring their performance represents a huge challenge for organisations. There is a lack of practical guidelines for all roadmapping steps, in particular for the regular update of an already implemented roadmap [5]. Ioannou et al. insist on the importance of the fact that for TRM to be successful, the strategic decision-making process has to be a collaborative one [6]. Thus, roadmapping has to take a mediating and networking approach which can happen by the integration of suppliers in the TRM process, a cross-functional approach to product and technology planning and vision building, as well as the ongoing coordination between corporate laboratories and business units [7]. Team members from different departments including both technical and commercial functions such as R&D, product development, manufacturing, marketing, finance, and human resources are involved in a consensus building process, which connects an expected future (descriptive) with a desired future (normative) [8]. Tolio et al. confirm this by investigating the co-evolution of products, processes and production systems in order to address challenges like new regulations, new materials, technologies, services and communications [9]. Putnik et al. discuss the scalability in manufacturing systems design and operation, using advanced and emerging design and management approaches and information and communication technologies to support their effective and efficient deployment in practice [10]. None of these articles, however, deal with a systematic and actionable approach to implement TRM for SPP in an industrial organisation.

Holmes et al. confirm our own finding that the evolution of roadmapping as a strategic decision support tool has been led by management practice rather than by theory [11]. Publications covering TRM are in general focused on explaining the value of roadmaps as decision support tool and the typical difficulties encountered during their deployment, rather than on practically usable approaches and/or best practice experience reports. In particular, we could not find any explicit treatment of TRM for strategic production planning in literature. Neither could we identify any collaborative or integrated design based approach to TRM and SPP in general. This represents a real problem for industries struggling to prepare themselves timely for the challenges, opportunities and risks that the fourth industrial revolution is about to bring along [12].

4. A design process for strategic production planning

In the context of a clearly structured and stage–gate process driven organisation, the entry challenge of executing a SPP project as a creative design process [13] is to propose a clear design process structure allows for a high degree of dynamics at the same time. Our approach is based on the model of problem solving published by Geschka [14] (Fig. 1).

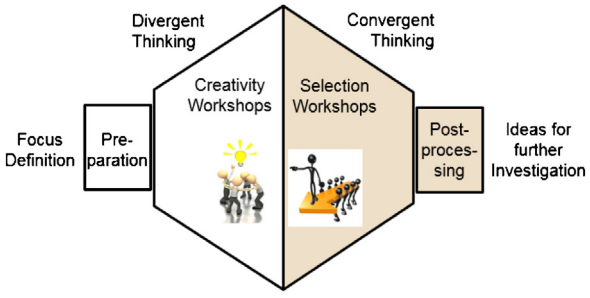

Fig. 1. Basic ideation process model based on Geschka [14].

The fundamental idea underlying this model is that in an integrated design process, the involved stakeholders shall run through a series of phases of divergent and convergent thinking. Every phase of divergence is a phase of idea generation and out-of-the-box thinking related to topics defined and prepared before. Experts from different domains work together in moderated creativity workshops, where the moderator's principal function is to help participants open up their minds to be able to get out of their boxes (i.e., contexts). The numerous ideas have to be consolidated and evaluated in the subsequent convergence phase whose principal objective is to decide how to proceed with each single idea generated during the previous phase. In moderated idea selection workshops, participants have to apply techniques facilitating idea evaluation.

A design process based on this fundamental ideation process element would be composed of an enchainment of several such elements, each element leading most notably to an increased level of concretisation of the ideas [15]. Typically, there are also multiple parallel paths, each path representing a particular set of ideas being worked out further. For the particular design problem of SPP, the authors proposed the schema depicted in Fig. 2.

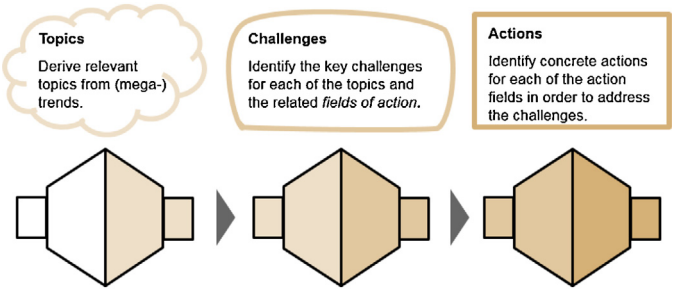

Fig. 2. SPP process based on integrated ideation process elements.

SPP seeks to find a creative yet systematic way to derive concrete actions to carry out to respond to trends that influence the organisation. These trends are manifold and related to several fields, such as technology, economy, ecology and society. The first process element deals with the identification of key topics derived from a list of (mega-)trends collected in the preparation phase, typically on the basis of relevant studies. Opening up the mind-set for the potential impacts these trends will have on the company is the key success factor for the divergence phase of this process element. Techniques like brainwriting, extreme scenarios, etc. are well suited to achieve this [16]. In the convergence phase, topics are prioritised, typically based on the company strategy, which requires the participation of top management representatives in the ideation team. The ranked topic list serves as the primary input for the subsequent process elements which deal with the particular challenges linked with each topic. Several such second-level elements might be triggered in parallel, depending on the process requirements and constraints in terms of time, resources and completeness (Fig. 3).

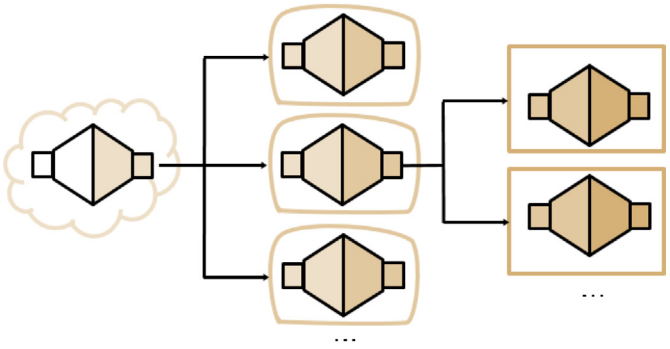

Fig. 3. Triggering process elements per topic and field of action.